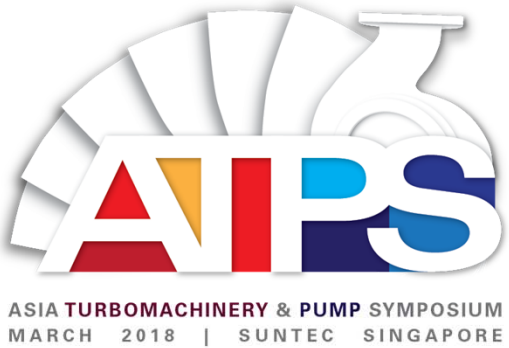

Investigation and Resolution of Governing Valve Linkage Failure for Compressor Drive Steam Turbine

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Abstract

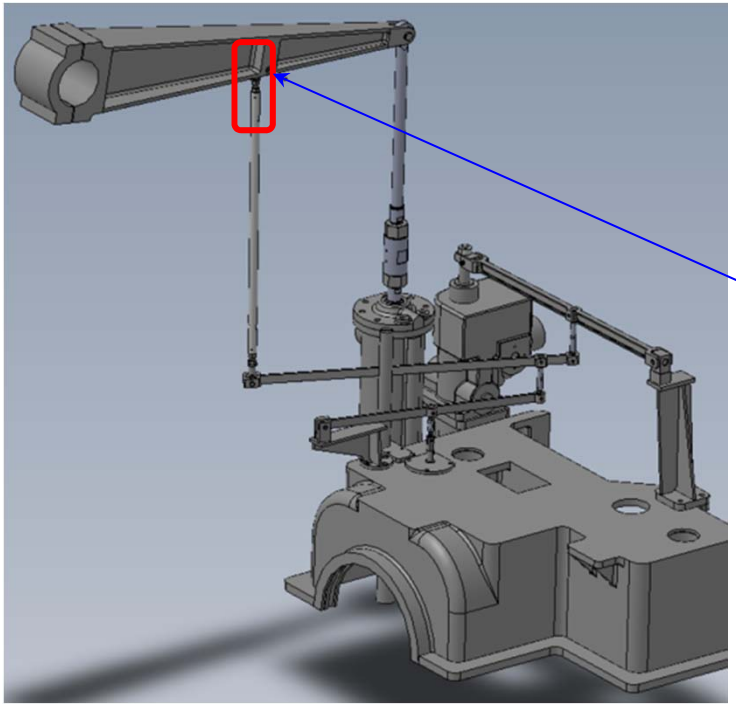
Fatigue failure of Governing Valve Linkage Rod end bearing and wear marks on several parts was observed on a extraction steam turbine (driving a centrifugal compressor) after it was in service for more than 9 year. The top surface of rod-end bearing was completely worn out.

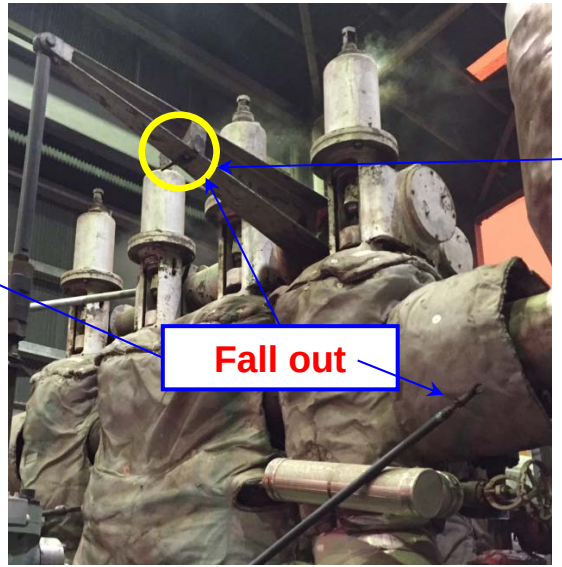
A detailed motion analysis was carried out to estimate the vibratory force and slip velocity of the Bearing ball and body. This paper presents the details of observations, inspections carried out and root cause analysis of the valve linkage failure along with the future recommendations.

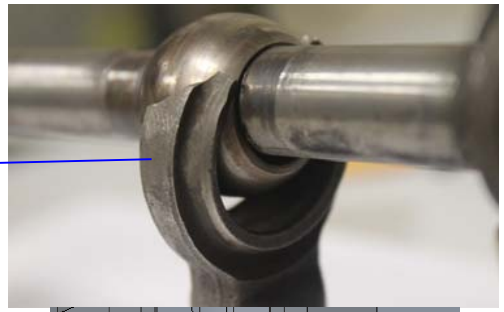
Contents

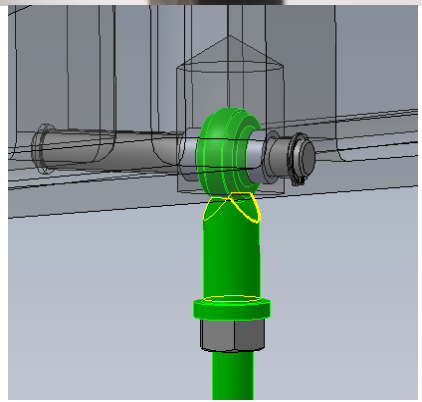
- Governing Linkage outline
- Rod-end bearing design
  - Static Loads
- Fracture analysis
- Possible cause
- Motion analysis and FEM analysis result
- Conclusions
- Recommendations
- Lesson Learned

Governing Linkage Outline







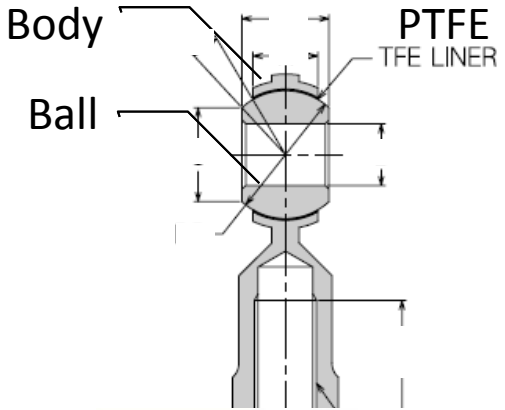


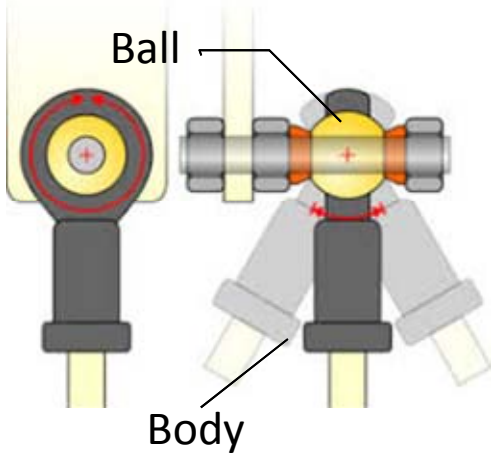
The rod end bearing failure occurred after the Turbine had been in operation for 9 years.

Rod-end Bearing Design

Material specification:

Material	PARTS	Hardness (HV)
Martensitic stainless	Ball	≥ 653
Austenitic stainless	Body	≤ 200
PTFE	Liner	N/A





Troubleshooting

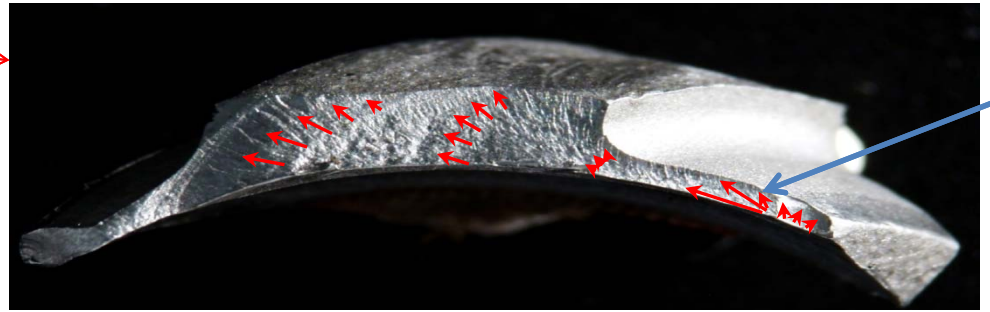
Problem	Possible Causes	Possibility
Bearing failure	High shock load	**Low**
	Improper strength at design stage	**Low**
	Corrosive fracture under severe environment	**Low**
	High pedestal vibration	**High**

- Strength and shock load were verified to be within criteria.

Fracture Analysis

Fracture

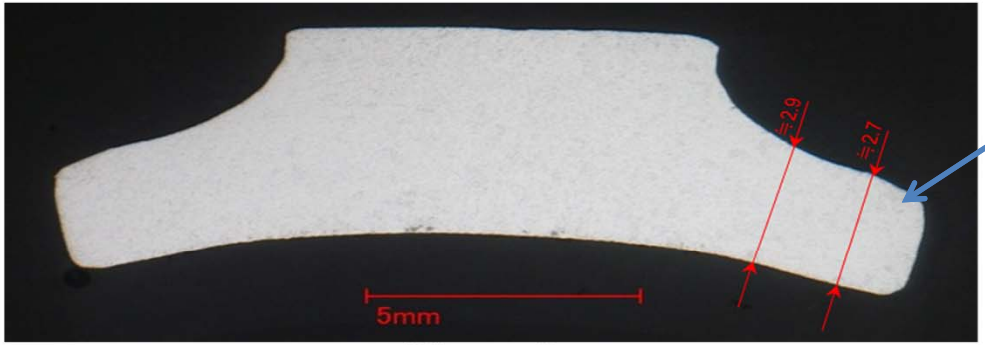
Failed Body



1mm remains

New RBT

Unused Body

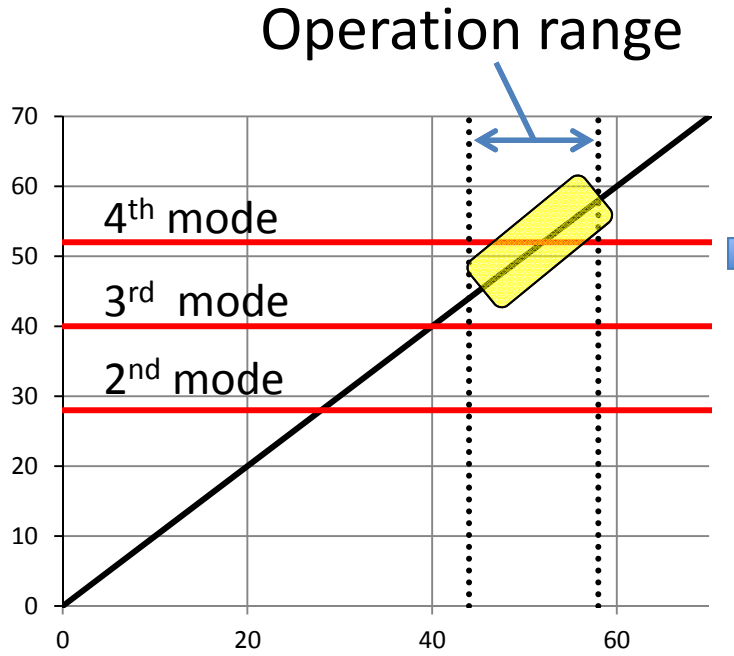


Y-Y cross section

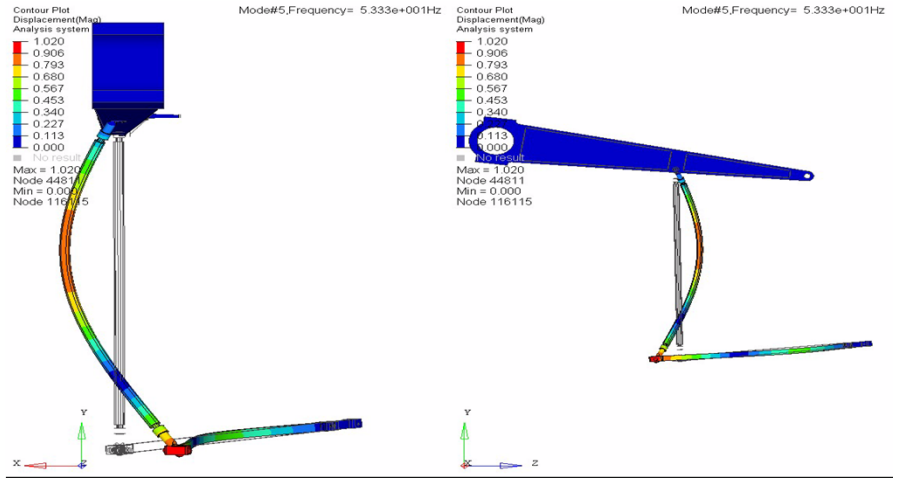
Approx. 3mm

Worn out thickness was roughly 2mm and striation pattern was observed which helped us identify fatigue fracture.

Possible Cause



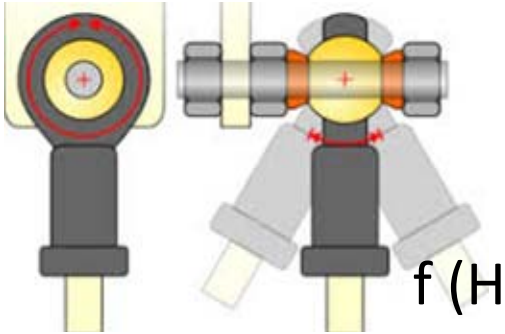
4th vibration mode



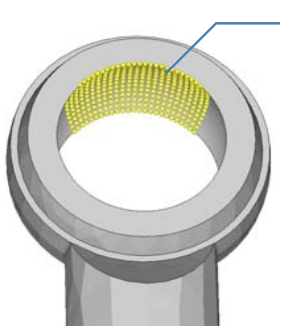
Fatigue fracture pattern and vibration analysis indicated that the 4th resonance mode falls in the Turbine operation range.

Scenario

- PTFE liner wore out due to resonance vibration (4th mode).

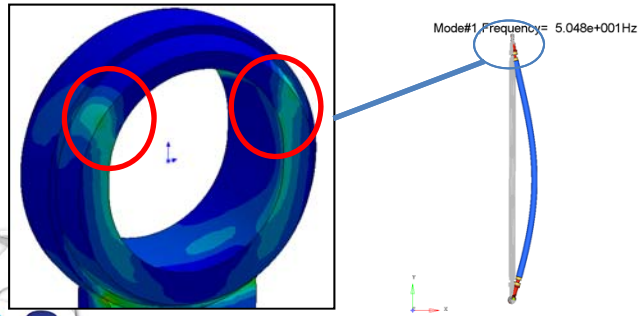


f (Hz)



Ball and body doesn't slip

- Bending stress occurred due to resonance vibration.

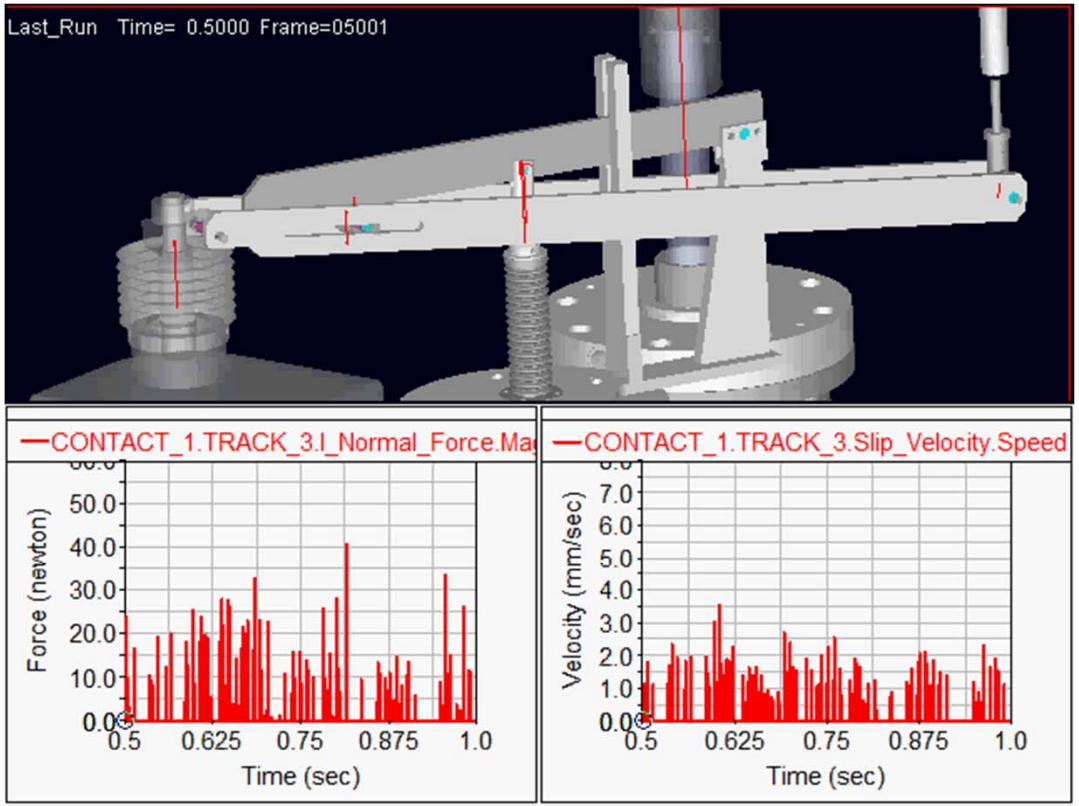


Failed due to repeated bending stress

Motion Analysis

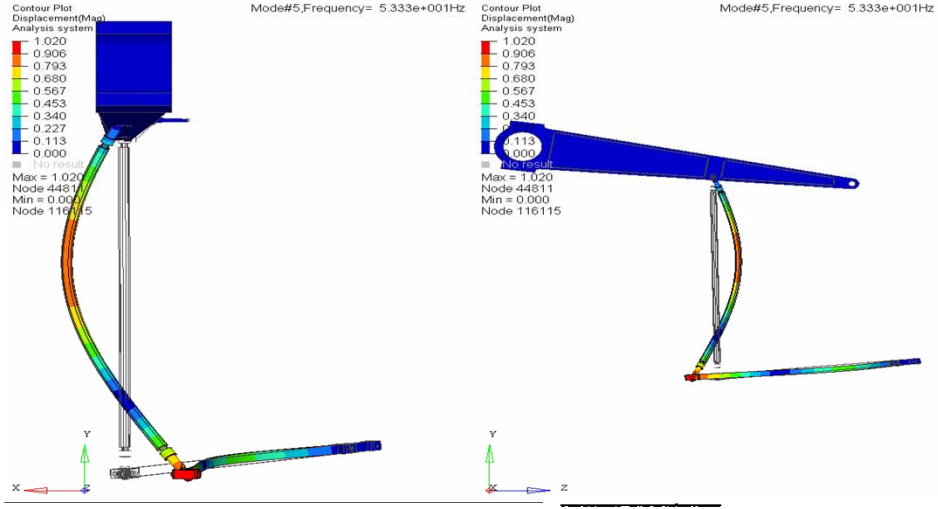
Multiple Linkages and Bearings makes it difficult to analyze the dynamic force

Excitation force was estimated using motion analysis with the help of static force.



- Dynamic Simulation

Bearing life estimation



(4th mode :51.6Hz)

Resonance mode

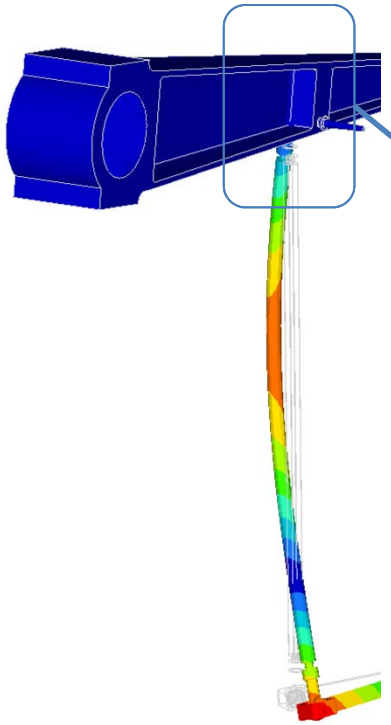
MAX.	3498 r.p.m
NOR.	3331 r.p.m
MIN.	2665 r.p.m

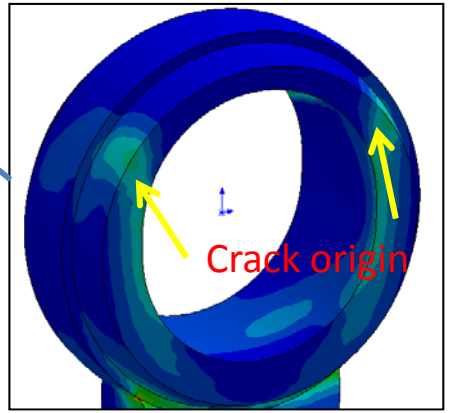
1. Excited force was estimated with motion analysis.
2. Q factor at resonance frequency was confirmed with hammering test.

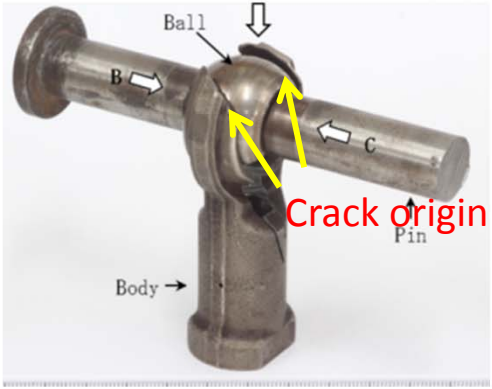
Slip velocity (5.6 mm/sec),
Lh = 16,644 hr (1.9 years)

Under resonance condition, PTFE liner will wear out within 1.9 years of operation.

Stress Analysis





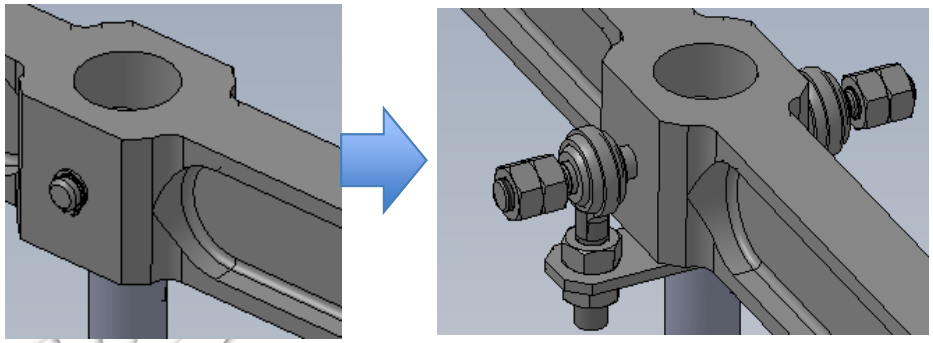


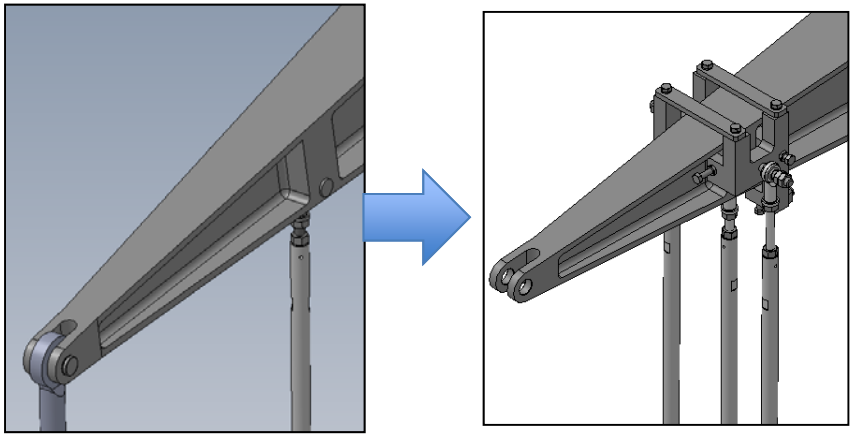
The peak stress points due to vibration at resonant frequency was found using FEA. They match the crack origin point of the failed bearing.

Recommendations

- *Plan 1 (Applied):* Provide separation margin from resonant excitation frequency.
- *Plan 2:* Improve system integrity using a redundant system.

Apply multiple rod end bearing





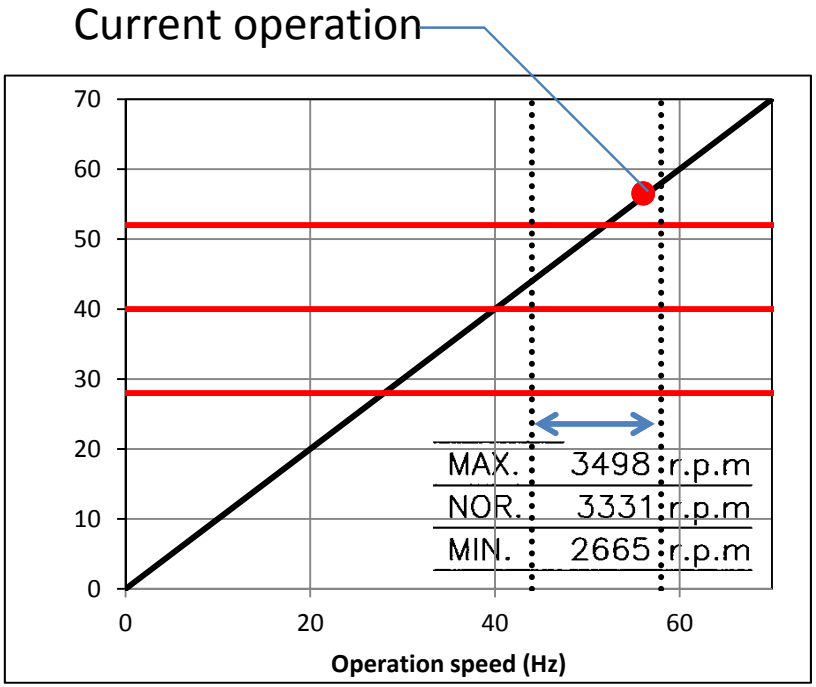
Recommendations

- Plan 3: Replace with Direct-drive actuator (Linkages are minimum).

Conventional Actuator
(Before Revamp)

Direct-drive Actuator
(After Revamp)

Results after maintenance



As a result of modification (Plan 1), turbine operation speed is far away from the resonance frequency.
No issues experienced after the maintenance.

Plan 2 will be carried out during next Turbine maintenance.

Plan 3 with minimum linkages can be carried out in the future

Lessons Learned

- Bearing Life should be considered at the design stage and bearing should be replaced at every maintenance (if bearing life is low).
- Dynamic stress and possibility of resonance should be addressed at the design stage.
- Root cause analysis and Motion Analysis is an useful tool in understanding the failure modes of Linkages and bearings.

Thank You…

Questions???